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# Use of 2D Multi Electrodes Resistivity Imagining for Sinkholes Hazard Assessment along the Eastern Part of the Dead Sea, Jordan

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**Abstract:** Sinkholes and subsidence are natural phenomena can be occurred in shallow geology sediments at different regions in the world. Sinkholes assessment is one of the most difficult near subsurface investigations. Geophysical prospecting is appropriate method to determine environmental and geotechnical problems. 2D multi electrodes resistivity imagining with Wenner-Schulmberge array was conducted within active sinkholes area. The objective of the survey is to detect features combined with sinkhole formation like zone of weakness, cavities and fractures. Soil in the study area contains alluvial, conglomerate and silty clay which represent good target for resistivity survey. The interpretation of resistivity data along the profiles show different model of the resistivity variation in active sinkhole zones compared with inactive zones in the study area. The deformation in the layer continuity and the direct contact between high resistive and low resistive layers can appear only in the subsidence area or active sinkhole zones.

**Key words:** Sinkholes, Dead Sea, Strike Slip Fault, Resistivity, Jordan

## INTRODUCTION

Sinkholes and subsidence are natural phenomena can be occurred in shallow geology sediments at different regions in the world. Sinkholes hazard assessment is one of the most difficult near subsurface investigations. It is clear that sinkhole formation is a dynamic process occurring over time, resulting in variations in the subsurface properties, such as porosity, fracture density, water saturation, etc. Variations in properties can be detected by geophysical methods as anomalies in the geophysical parameters such as gravity anomalies, seismic velocity, and electric resistivity[123]. The first experience of the Continuous Vertical Electric Sounding (CVES) method use in the Dead Sea western shore have shown its high potential for study of the sinkhole problem in shallow subsurface[4]. The clear resistivity anomalies connected with the soil properties variations were detected at the sinkhole development sites of the different geology in the western [5 6].

In the present study, performed in framework NATO Science for Peace Programme, 2-D multi electrodes resistivity imagining with Wenner-Schulmberger array was conducted within active sinkhole formation area. The aim of the survey was to detect features combined with sinkhole formation like zone of weakness, cavities and fractures.

The study area is located along the eastern side of the Dead Sea shoreline, locally called Ghor Al-Haditha. The area is covered by alluvial fan, which consist of fine coarse-grained silica, sand and pebble size gravel with thin intercalations of laminated marl of Holocene age. The alluvial deposit calculated to be good shallow aquifer and one of the primary source, supplies domestic, municipal, agriculture and industrial water to the region. The water in the alluvial aquifer has historically been fresh and suitable for most potable uses. The water quality in the eastern side of the Dead Sea shoreline is good and the salinity rarely exceeds 800 ppm; it is slightly alkaline (pH 7.5-8.0), calcium and magnesium are the predominant cations, and bicarbonate the most important anion.

Over the last twenty years the total dissolved solids (TDS) levels have risen in wells located along the Dead Sea shoreline due to the excessive pumping, poor water resources (low precipitation and high evaporation) and poor management of water resources. The excessive exploitation of groundwater aquifers leads to water

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table drawdown and subsequently to the contamination of the aquifers.

The drawdown of the groundwater table leads to appear the sinkhole phenomena in the study area during the last two decade and affects the agriculture parcels, power lines, water buried pipes, transportation roads and residence structure.

The aim of the study is to determine any subsurface anomaly detected by resistivity imaging to delineate the potential collapse area and compared the resistivity changes beneath a known active sinkhole zones and inactive zone.

Sinkholes with different diameters and depth are scattered in the area but most sinkholes. The survey was conducted at the eastern side of the Dead Sea, east of the Lisan are concentrated at agriculture parcels with high irrigation (Fig. 1). In the same figure we have shown both the sinkholes distribution (taken from the Taqquetdine *et al.,* [7]. and CVES line lay-outs. I think latest sentence have to be shifted to the discussion part-M.E).

**Site Description And Geological Setting:** The study area located along the Dead Sea shoreline. The area is almost flat with altitude of about 375 to 400 m below the sea level (bsl). The climate is very hot in summer (May to august) with temperatures in excess of 45° and less than - 5 in the eastern highland in winter (November to January). Rainfall is rare, but it is much higher and exceeds more than 200 mm in the eastern highlands[7].

The area is almost located to the west of the Dead Sea Fault area in an area of active faulting, and located between two main wadis Wadi Mutayl to the north and Wadi Ibn Hamad to the south, both wadis run from the eastern highlands to the Dead Sea in the west.

The area is covered by different types of sediments represent different formations (Fig.2).

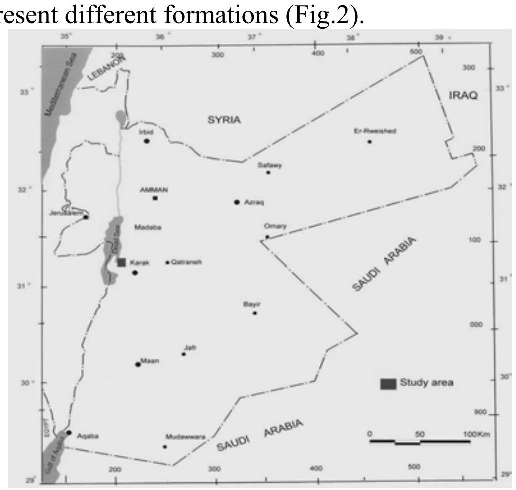


Fig.1:Location map of the study area

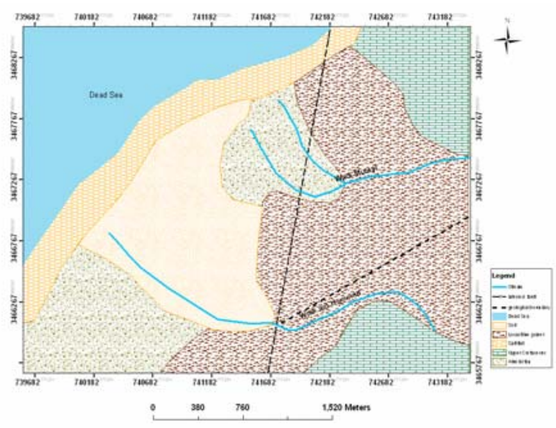


Fig. 2: Geological map of Ghor Al Haditha Area modified after [7]

The Lisan Formation composed of alternating colored lamina the grey lamina dominated by Calcite with gypsum and quarts. The white lamina is dominated by Aragonite with less amount of gypsum and rare traces of Quarts and Calcite. The age of the Lisan formation is upper most Pleistocene.

The Usdum formation is made almost totally of Rock Salt (Halite) with rare horizons of Carnalite and Shale. These salt layers seem to exist below almost all of the present Dead Sea[8].

The Dana conglomerate formation consists mainly of Pebbles to Boulder Conglomerate comprising well rounded, poorly graded, Clast of Chert, Chalk and Chalky Limestone. The matrix is fine-grained Sandstone and granular size Calcarenite.

The superficial deposits in the area is composed of fluviatile and lacustrine gravels of Pleistocene Age which is mostly unconsolidated gravel and composed of poorly sorted, and subangular to rounded local bed rock clasts; it is partly calcreted[9]. Holocene to recent sediments comprise alluvial sediments, calcrete and soil.

**Field Survey Method And Instruments:** The 2-D electrical imagings of subsurface resistivity distribution are generated. Using this method, features with contrasting electrical properties to that of surrounding material may be located and characterized in terms of resistivity, geometry and depth of burial. Resistivity data used in the electrical imaging are typically collected using computer controlled measurement system connected to surface multi-electrode arrays. The field data are inverted to produce models of subsurface electrical properties. Inversion algorithms used to generate 2D resistivity models have been available for many years, and consequently 2D imaging has regularly been applied to geological, engineering and Hydrogeological problems[10].

The 2D imaging used the Wenner–Schlumberger; the electrode array arrangement is a mixture between Wenner and Schlumberger arrays by which the resistivity changes in both the vertical as well as horizontal direction can be detected along the survey profiles. The above electrode arrangement array combines the advantages of the two separated arrays. The apparent resistivity for Wenner –Schlumberger array:

$\rho = pi\ n\ (n+1)\ a\ R$

where R is the measured resistance, *a* is the spacing between the P1 and P2 electrodes and *n* is the ratio of the distance between C1-P1 and P1-P2 electrodes. The depth of investigation increased as the spacing between the potential electrodes P1-P2 is increased 2*a* and the measurements are repeated for n equals to 1, 2, 3, 4, 5 and 6.The P1-P2 spacing is increased and the same sequence measurement repeated (Fig.3).

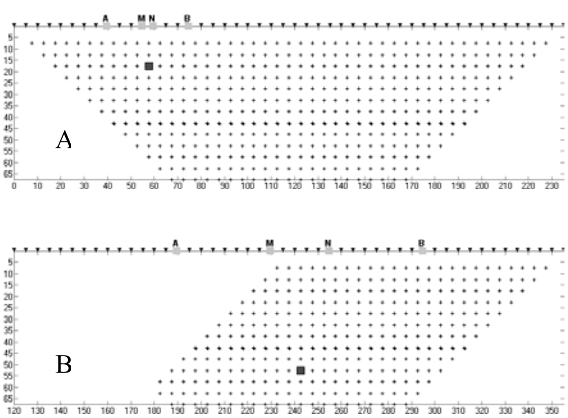

Fig. 3: The arrangement of electrode for a 2-D electrical survey and pseudosection data pattern for the Wenner-Schlumberger arrays

The survey was carried out using Syscal –Pro system (IRIS instruments) with 48 multi- electrodes system, with two 24 electrodes cables with 5 m electrode spacing were arranged along a profile, data level n=11 was chosen along all the profiles with 24 m investigation depth. The profile extended using a roll along technique[11]. The multi-electrodes were performed using Wenner-Schlumberger configuration. The electrodes location and elevation were measured by GPS.

**Data Processing:** The resistivity data was processed using RES2DINV program that automatically generates a two-dimensional resistivity model for subsurface from electrical imaging surveys[10 12 13]. The program can large data sets collected with large number of electrodes and can account the topographical effect along the survey lines (Loke 2000). The Root-Mean-Square (RMS) error quantifies the different between the measured resistivity values and the calculated from true resistivity model. The average RMS error of the profiles was less than 10%.

## RESULTS

2D-Multi-electrodes resistivity survey was conducted along four profiles at the study area, two of then were laid out in an active sinkhole zone and the others in inactive zone. Most the measurements were carried out in agriculture parcels between Wadi Mutayl and Wadi Ibn Hammad (Fig. 4).

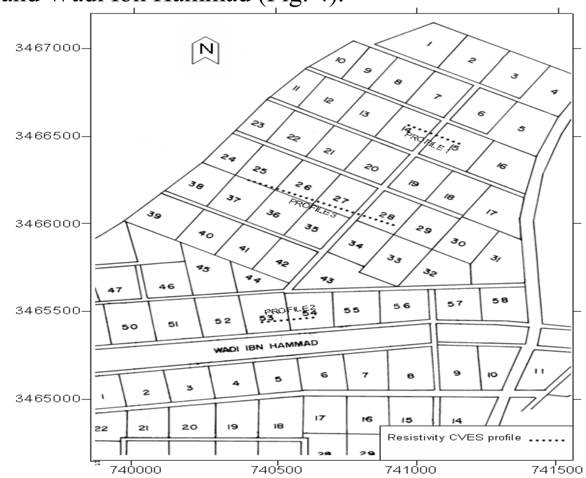

Fig. 4: CVES line lay-outs

Profile 1 is 350 m long and conducted at vegetation land with high rate of irrigation the western section of the profile located at active sinkhole zone (Fig.5).

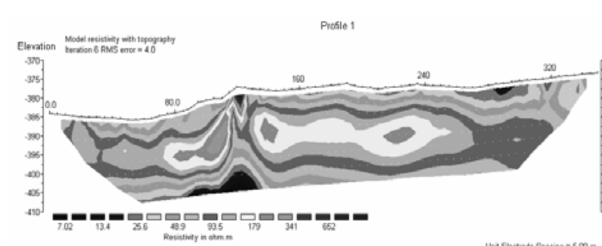

Fig. 5: The resistivity cross-section along profile 1

The low resistance layer between 25 and 90 Ohm-m along most of the profile represent silty soil with ground moisture. The moderate resistive layer between

95 and 250 Ohm- m at elevation -385 bsl m and extended until the bottom of the profile. The high resistive value at the surface between horizontal distance 117 and 120 m associated with asphalt roadway.

At elevation -405 m bsl a very low resistivity layer less than 20 Ohm-m extends along the western part of the profile beneath the active sinkhole zone.

Profile 2 is 350 m long; the moderate resistivity values dominate the eastern part of the profile which represents agriculture land. The continuous high resistive layer more than 600 Ohm-m at the surface between horizontal distance 65 and 165 m and between elevation -380 bsl and -392 m located over the active sinkhole area covered with high fractured alluvial (Fig. 6).

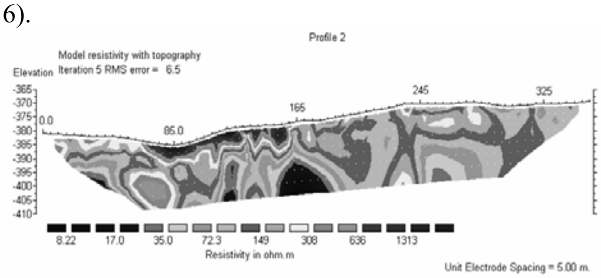


Fig. 6: The resistivity cross-section along profile 2

The low resistance values less than 30 Ohm-m represented by two low resistive zones located at horizontal distance 120 and 165 m. These two zones located beneath the active sinkhole zone at elevation -392 m bsl and extended vertically to the bottom of the cross section. Profile 3 is 590 m long, the resistivity changes vertically along the first 400 m. The moderate resistive layer between 95 and 250 Ohm- m at elevation -380 bsl m at the south-east part of the profile the thickness of this layer extended increased toward the north-west of the profile. The continuous high resistive layer more than 500 Ohm-m between horizontal distance 0 and 390 m and between elevation -390 and -392 m bsl (Fig. 7).

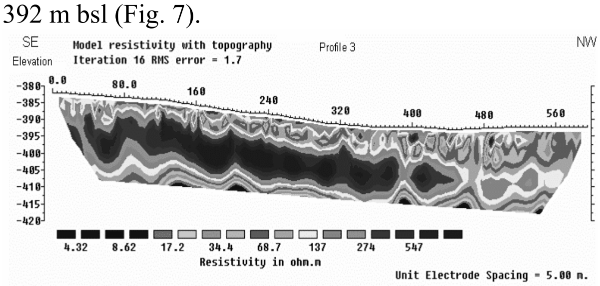


Fig. 7: The resistivity cross-section along profile 3

The low resistance values less than 30 Ohm-m extends along the bottom of the cross section and extends horizontally.

At the western part of the cross section where the resistivity changes horizontally and vertically represent the active sinkholes area and the three high resistive zones at horizontal distances 400, 450 and 810 m represented known buried sinkholes.

## DISCUSSION AND CONCLUSION

The resistivity imaging gives image of the subsurface resistivity changes at sinkhole area. The electrical sections along the profiles in the study show different types of resistivity zones.

High resistivity material more than 500 Ohm-m represent dry soil or sand with gravels or asphalt roadway or buried known sinkholes. The moderate resistive layer between 95 and 250 Ohm- m represent soil with ground moisture. The low resistance layer between 25 and 90 Ohm-m along most of the profile represent silty soil with moisture. Very low resistivity layer less than 20 Ohm-m may represent saturated clay.

The distortion in the resistivity values in this location along this profile indicates the change in the material resistivity in the active zone. The resistivity changes randomly in both horizontal and vertical direction in active sinkholes areas.

The high infiltration transports the surficial materials downward along cracks and cavities that formed by erosion process beneath the soil cover [14]. The location of the most sinkholes in the area between two main wadis and presence of high irrigation in the agriculture parcels increase the internal erosion and piping features by washing the soft materials cause erosional channels.

In the other hand the seepage water and the presence of clay layers beneath some profiles cause clay swell. When the amount of water in the clay zones decrease the clay layers reduce in size causing surface cracks and depressions.

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